SOI 30 Day Reports

FK140307 Report

1. Ship Name: R/V Falkor

2. Cruise Dates: 07/03/2014 to 11/04/2014

3. Cruise Number: FK140307

4. Ports-of-Call: Honolulu, Honolulu

5. Participating Organizations: University of Hawaii's (UH) Hawaii Undersea Research Laboratory, UH Department of Geology and Geophysics, UH Hawaii Mapping Research Group, NOAA Office of National Marine Sanctuaries (ONMS) and the Papahanaumokuakea Marine National Monument (PMNM), NOAA Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division (CRED), NOAA National Observer Program (NOP), Woods Hole Oceanographic Institute (WHOI), the National Science Foundation (NSF), and the University of Sydney School of Geosciences.

6. Geographic Areas: All project operations took place in the Papahanaumokuakea Marine National Monument in the Northwestern Hawaiian Islands. The primary areas of operation within the monument were seamounts and banks located in UTM Zone 1. Additional secondary areas of operation included Maro Reef and West Northampton Seamount located in UTM Zone 2.

7. Names and addresses of the on board Chief Scientist and Co-chief Scientists:

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8. Cruise Objectives

The title of this project was "Volcanic platforms, ancient reefs, ridges, and seamounts: mapping the Papahānaumokuākea Marine National Monument". The following are the 4 original objectives described in the proposal and two additional objectives that were added after the proposal was accepted.

Objective 1: Map seamounts and rift zone ridges located in the northern half of the monument. This survey focuses on Mn-crust habitats and the discovery of new high density coral and sponge beds that are associated with seamount and ridge topography.

Objective 2: Map drowned reef terraces on Gardner Pinnacles that reach depths of at least 2,000 m. The focus will be to complete mapping that has already been started, thereby improving our understanding of the geologic history of this important volcano.

Objective 3: Map the 50-150 m depth range around Laysan Island, Gardner Pinnacles, Pioneer Bank and if time permits, Raita Bank. The focus will be on the monument's important mesophotic zone habitats however drowned reefs are also found in this depth range. This objective will therefore be synergistic with objective 2.

Objective 4: Complete mapping the ridge southeast of French Frigate Shoals, with a focus on providing full coverage of an important internal tide generation site. As part of this last objective, we are also requesting approval to deploy an oceanographic instrument mooring owned by the University of Hawaii's Department of Oceanography to record data on the velocity and density structure of the water at this site for two fortnights or approximately 28 days.

Objective 5: Acquire gravity and magnetics data for the purpose of identifying the precise origin and locations of the volcanoes under the various banks and seamounts in UTM Zones 1 and 2 of the monument.

Objective 6: Document encounters with cetaceans and monk seals inside the monument for the purpose of improving our understanding of the effects of multibeam sonar on marine mammals.

9. Cruise Summary (A)

As indicated in section 8, the objectives of this cruise changed between the time the proposal was accepted and when the cruise took place due to a number of events. First, the PI was informed that the oceanographic mooring would not be available for the cruise, thereby reducing objective 4 to simply completing the mapping of the French Frigate Shoals ridge. Secondly, the PI was originally awarded 36 days for this project but later informed that he had been awarded 36 addition days to continue mapping in the monument due to a scheduling issue with the ship. Two long cruises separated by only 3 weeks presented a staffing issue since most of the participants on the first cruise were unavailable for the second. Therefore a decision was made to conduct both cruises, but primarily the second, as components of a graduate level Spring semester course for the University of Hawaii (UH) Geology and Geophysics Department (i.e., G&G 614 Field Study) under the instruction of Michael Garcia (land-based instruction) and this project's PI and chief scientist, Christopher Kelley (at sea instruction). The third event was that one of the graduate students (Jonathan Tree) and his faculty advisors Michael Garcia and Garrett Ito were able to secure both a magnetometer from UH and a gravimeter leased

from the Woods Hole Oceanographic Institute (WHOI) with funding assistance provided by the National Science Foundation (NSF). Therefore a fifth objective materialized which was to simultaneously acquire gravity and magnetics data during the multibeam mapping surveys on both cruises and in several cases, conduct lines over existing multibeam data solely for the purpose of acquiring these two additional types of data. The summary of our findings for this objective are provided in section 10 (B) below.

The fourth event took place during the monument permit application process. A considerable amount of discussion arose regarding the possible effects of multibeam sonar on the marine mammal populations in the monument. While researching this issue, it became apparent that no documented observation data existed on the reaction of marine mammals to multibeam sonar. Concerns about negative effects led to the incorporation of a number of operational requirements in our permit, one of which was the posting of a marine mammal observer on Falkor's upper deck during all daylight hours. Instead of just trying to meet this requirement in our permit by simply posting a lookout, we chose to create a sixth objective for the project, mentioned in section 8. We identified a trained marine mammal observer from the NOAA Observer Program interested in participating on the cruise who would oversee efforts to carefully document each and every encounter with any species of marine mammals.

Final changes to the original proposal objectives were the extension of our maximum targeted mapping depth from 3,000 to 4,000 m and the "spreading out" of the objectives over two instead of just one cruise. As a result, this first cruise focused primarily on objectives 1, 5, 6, and to a lesser extent, objective 3.

Multibeam Surveys

This cruise was one of the more successful multibeam mapping efforts the chief scientist had ever been on. No days were lost to mechanical problems, instrument problems, or weather and the acquired data are of very high quality. Based on captain Bernd's prediction of poor weather when we were scheduled to arrive at the northern end of the monument, we spent two days during our transit up mapping further south off Maro Reef and West Northampton seamount until the weather system passed. Mapping was conducted 24 hrs a day during all 36 days of this cruise, with the exception of the periods between Honolulu and the monument boundary on March 7 and April 11, when the systems were purposely turned off. Within the monument, 61,000 km^2 of seafloor were mapped that included a total of 18 seamounts (Figs. 1 and 2). Only nine of these seamounts currently have names and include Academician Berg, Turnif, Woollard, Wentworth, Nero, Ladd, Gambia Shoals, East of Salmon, and Bank 9. The other 9 seamounts still need to be named, which will hopefully happen as a result of this cruise. Additionally, we added extensive mapping data for the deeper areas off Kure, Midway and Pearl and Hermes Atolls, which had only been partially mapped by other ships. As a result of this cruise, all significant features in the UTM zone 1 area of the monument are now completely mapped.

Perhaps the most interesting finding of our surveys is that there are at least four different types of volcanic features present in this northern area of the Monument including 1) atolls that are presently at the surface, 2) flat-top seamounts that have summits within 70 m of the surface, 3) flat-top seamounts that have summits at depths of over 1000 m, and 4) seamounts with peaked summits at depths below 1000 m (Fig. 2b). We believe that the deeper seamounts, peaked and flat-topped, are much older (70-80 million years) than the shallower seamounts and atolls (25-30 million years), and may not be Hawaiian in origin. These potentially Cretaceous era dormant volcanoes were likely carried into the vicinity of the Hawaiian Archipelago by the movement of Pacific Tectonic Plate. When they arrived near the Hawaiian hot spot, active local volcanoes may have erupted through or around them creating a confusing mosaic of young and old seamounts in this area of the monument. This scenario is supported by the appearance of Bank 9, which seems to be a composite of both a younger Hawaiian seamount and older Cretaceous seamount. However, additional work involving rock sampling and analyses needs to be carried out to confirm this hypothesis.

Cetacean Observations

A total of 29 encounters with marine mammals occurred and were documented on this cruise. The locations of the encounters are shown in Figure 3. The species included sperm whales, humpback whales, pilot whales, dolphins, a monk seal, and several unidentified species due to distance and the brevity of the encounter. Given that this cruise was conducted during the time of year when humpback whales typically migrate back north from Hawaii, we were surprised by the relatively low number of encounters with this species in the monument. A second point of interest was the higher density of sperm encounters off the west side of Maro reef. In all cases, the trained observer did not see any obvious negative reaction by any species that came within the multibeam sonar ensonification volumes. All of the behaviors such as “spy hopping” were typical of those seen by the trained observer on other boats and ships not engaged in mapping activities.

10. Cruise Summary (B)

Gravity Surveys (prepared by Jonathan Tree)

The Bell BGM-3 marine gravimeter outputs hourly logs and one daily log of gravity data that can be used for processing and data analysis (data files with suffix of *.GEF and *.RGS respectively). Daily processing was completed after the GMT day was finished and one full day of data along our track was available. Traditional gravity data processing was completed by filtering the gravity data string using filter tools from Linux and Generic Mapping Tools Version 4.5.12. The data reduction steps taken include resampling on 15 second increments, applying a spatial and vector correction to account for our location on the Earth and our velocity in a given heading (termed the Eötvös correction), and lastly the removal of the Earth’s gravitational field by the IGRF 1984 approximation for gravity. Qualitative observation of this data was conducted using MATLAB and quality individual “lines” were extracted from the continuous dataset of the day’s duration. The quality of the line was defined as containing no anomalous data

spikes that correlate with sharp turns of the ship or other unknown data interference. The product of this reduction is called the Free-air Anomaly and is plotted in the supplementary Figure 4. This is the baseline product that will be analyzed further and submitted to the NGDC for archiving once full analysis has been completed. This future work will focus on geophysical questions such as:

1. By locating extraordinarily dense subsurface structures relict from volcanic magma chambers, how many individual volcanoes were formed in this region of the Hawaiian Chain?
2. How much of the volcanic materials were extrusive (i.e., lava flows on the surface) vs intrusive (i.e., magma filled chambers, dikes, and sills)?
3. How strong is the lithosphere that holds up these volcanoes? Does this strength change when a larger or smaller volcanic load is emplaced atop of it?
4. Not all of these seamounts were formed from the Hawaiian hotspot, which ones are Hawaiian volcanoes and which ones are older Cretaceous seamounts that were present long before the Hawaiian volcanoes erupted on to the seafloor?

Data that was collected in this region fills a large hole in the existing geophysical data of this region, making these data invaluable to the marine geophysical community (Figure S4). Where previous gravity surveys were focused on larger features, the data we collected was focused on seamount summits and flanks. Due to the nature of the bathymetric survey plan, we will be able to fully locate and image most of these seamount's volcanic centers and quantify the dimensions and physical properties of once active magma chambers that fed these volcanoes.

The Bell BGM-3 is a power and motion sensitive instrument, and consequently, any disruption to these elements will yield "non-valid data". Providentially, only minor amount of data were lost due to these conditions and does not significantly inhibit our dataset. Rough sea state was our only source for these mechanical malfunctions which occurred twice briefly (one hour of stationary data disruption) during two CTD casts and once on transit through rough waters over featureless seafloor.

Magnetics Surveys (prepared by Brian Shiro)

The Geometrics G-882 marine magnetometer collected 28,010,619 measurements of the total magnetic field throughout the FK140307 cruise between 7 March 2014 and 11 April 2014. The instrument was towed 169 meters behind the *Falkor's* aft deck A-frame at an average depth of approximately 9 meters below sea level depending on the ship's speed. Raw data was collected at 0.1 second intervals and stored redundantly via both the SCS and Hypack systems. Science watchstanders monitored the magnetometer's data stream in the Science Control Room and logged its activity every hour for the duration of the cruise.

Since the magnetometer data did not include geographic position, it was necessary merge the 10 Hz magnetometer data with the ship's 1 Hz navigation data by decimating them to a common time sampling using a one-second median filter. The gridded total field data shown in Figures 5 and 6 illustrate how the FK140307 cruise improved magnetic data

coverage compared with pre-existing data from other sources. Going forward, we will further reduce the data by subtracting the International Geomagnetic Reference Field (IGRF), applying the Reduction to Pole (RTP) correction, and performing a crossover analysis. This will draw out small-scale magnetic variations that can provide relative age constraints on features identified in the sonar and gravity data. Thus, the magnetic information could prove to be an age discriminator to distinguish Hawaiian age from Cretaceous age seamounts within the Papahānaumokuākea Marine National Monument.

11. Summary of Measurements and Samples Taken
Yes

NO	UNITS	DESCRIPTION
60,880	Square Kilometers	EM 302 Multibeam bathymetry data with a depth range of 30-5,543 m
60,880	Square Kilometers	EM 302 Multibeam backscatter data with a depth range of 30-5,543 m
2,869	Square Kilometers	EM 710 Multibeam bathymetry data with a depth range of 30-2,315 m
2,869	Square Kilometers	EM 710 Multibeam backscatter data 30-2,315 m
14,585	Kilometers	Gravity data with continuous data feed along ship track
14,585	Kilometers	Magnetometer data with continuous data feed along ship track
19	Stations	CTD Casts providing depth, salinity, temperature, and sound velocity to a maximum depth of 1000 m
10	Stations	XBT Casts providing depth, temperature, salinity, and oxygen to a maximum depth of 760 m
29	Observations	Data records of cetacean encounters that include location, date, time, species, and behavior

12. Moorings, Bottom-Mounted Gear and Drifting Systems
No

13. Equipment Used

The following types of equipment were used during this cruise.

a) *R/V Falkor*'s Kongsberg EM 302 multibeam sonar
This instrument is owned and operated by SOI and is permanently mounted on the *R/V Falkor*. A link to a downloadable document providing complete specifications is provided on the following Kongsberg website:
http://www.km.kongsberg.com/ks/web/nokbg0397.nsf/AllWeb/A915A71E90B6CFAEC12571B1003FE84D/$file/306106_em_302_product_specification.pdf

b) *R/V Falkor*'s Kongsberg EM 710 multibeam sonar
This instrument is owned and operated by SOI and is permanently mounted on the *R/V Falkor*. A link to a downloadable document providing complete specifications is provided on the following Kongsberg website:
http://www.tdi-bi.com/vessels/em710_.pdf

c) *R/V Falkor*'s CTD
This instrument is owned and operated by SOI and was used to acquire sound velocity profiles for the multibeam sonar systems. A description is provided on the SOI website:
http://www.schmidtocean.org/story/show/47

d) *R/V Falkor*'s Expendable Bathythermographs (XBTs)
These instruments provide a cheap time efficient means of acquiring sound velocity profiles for the multibeam sonar systems. A link to a downloadable document providing a description of the Deep Blue XBT used is provided below:
http://www.sippican.com/stuff/contentmgr/files/0dad831400ede7b5f71cf7885fdeb110/sheet/xbtxsv.pdf

e) Bell Aerospace BGM-3 marine gravimeter
The BGM-3 Gravimeter is a geophysical device that measures accurately and precisely the acceleration of gravity due to the Earth's gravity field. This device was rented from Woods Hole Oceanographic Institute's 'WHOI' organization: the Multidisciplinary Instrumentation in Support of Oceanography 'MISO' and is part of their Potential Fields Pool Equipment 'PFPE' that was installed by WHOI engineers on March 5-6, 2014. The device was located in the dry lab, slightly above water level and slightly portside of the ship's centerline. The gravimeter was land tied prior to departure on March 6th, 2014. Data from the BGM-3 was continuously logged along the ship track and was paired with the *R/V Falkor*'s navigation data from the *Falkor*. Output measurements of observed gravity were expressed in units of mGal.

f) Geometrics G-882 marine magnetometer
A Geometrics G-882 marine magnetometer was provided by the University of Hawaii. The device works by detecting variations in the resonance of a self-oscillating split-beam cesium vapor. It has an accuracy of <3 nT over an operating range of 20,000 nT to

100,000 nT. The G-882 was attached to a multiconductor tow cable that was paid out to a maximum of 169 meters from the stern of the ship using an electrical winch on the *Falkor's* aft deck and supported by the ship's A-frame. The offset between the A-frame and the ship's GPS antenna is 22 meters, giving a total offset of 191 meters between magnetometer and the ship's logged geographic coordinates. The raw data was digitized by the Geometrics DC/Data junction box in the *Falkor's* dry lab and then logged via an automatic rsync process to the ship's SCS system on channel COM28. Falkor marine technicians also chose to log the data independently via the ship's Hypack system. Data was logged continuously at 10 samples per second (10 Hz) and included a timestamp, gamma value in nT, Larmor frequency level, and scaled instrument depth.

14. Station Plots

Two Google Earth images were emailed to "cruise.report@schmidtocean.org" showing Fig. 1) the ship track and positions of CTD (red) and XBT (green) casts, and Fig. 3) locations of all cetacean observations made on this cruise.

15. Other

a) Three graduate students were among the participants on this cruise, two from the University of Hawaii's Department of Geology and Geophysics and one from the University of Sydney's School of Geosciences, Geocoastal Research. All three gained considerable experience in carrying out projects at sea on large oceanographic vessels and were required to learn the basic functions of Hypack 2013 for survey line planning and magnetometer data acquisition, Seafloor Imaging Systems (SIS) for multibeam data visualization and acquisition, Saber and Caris for multibeam data editing and processing, SVP editor and Turo XBT for XBT data acquisition and processing, and Fledermaus for multibeam bathymetry and backscatter data visualization and display.

b) A post-cruise data management meeting was held on June 27 to create the plan for distributing the data collected on both this cruise and the second cruise for this project (FK140502). The meeting was attended by participants from UH and NOAA CRED, with SOI's Allison Miller listening in via Skype. Following the creation of a metadata file by the PI, the plan includes the submission of raw and edited data files to the NOAA National Geophysical Data Center (NGDC) by the end of July, 2014. Processed bathymetry and backscatter data in the form of GRDs, ASC, and image files will be posted on the Hawaii Undersea Research Laboratory's (HURL) website. Other websites including PMNM, NOAA CRED, and SOEST will also either be a source for the data or will provide a link to the data on the HURL website. CTD and XBT data will be provided to Pat Caldwell of NOAA's National Oceanographic Data Center (NODC). Cetacean observation data and the GIS project created from the data will be provided to NOAA Pacific Islands Regional Office (PIRO) that is responsible for protected resources and Endangered Species Act (ESA) section 7 consultations.

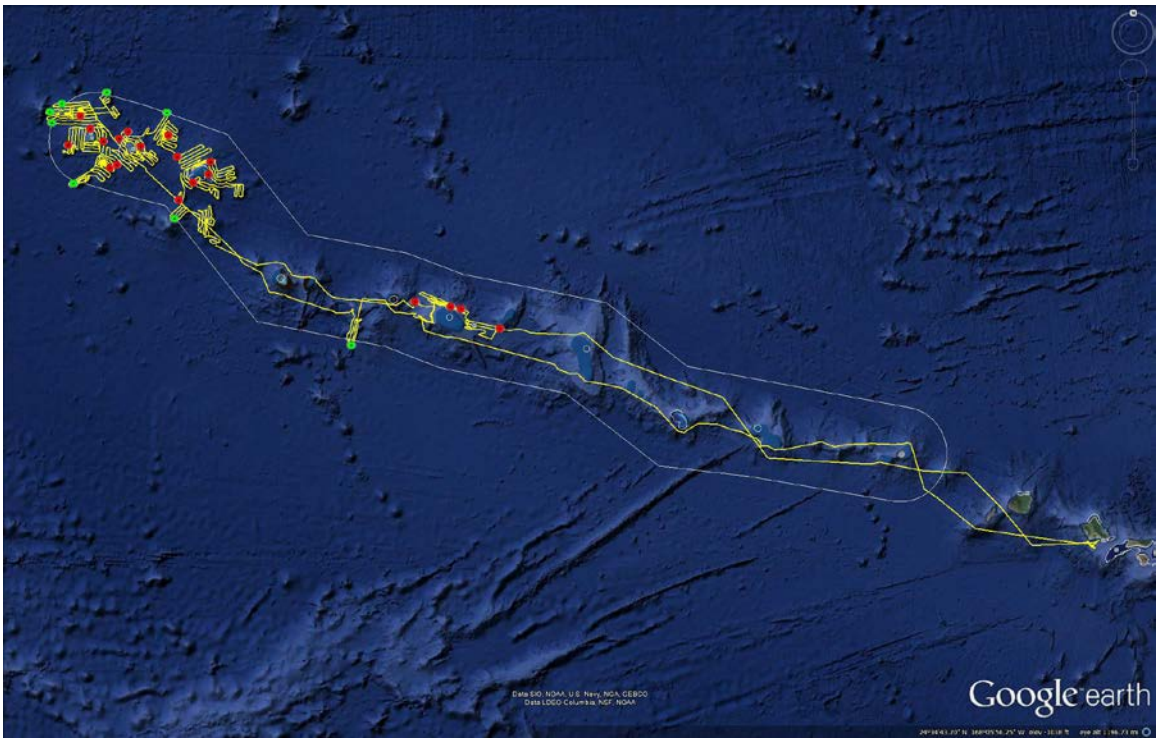
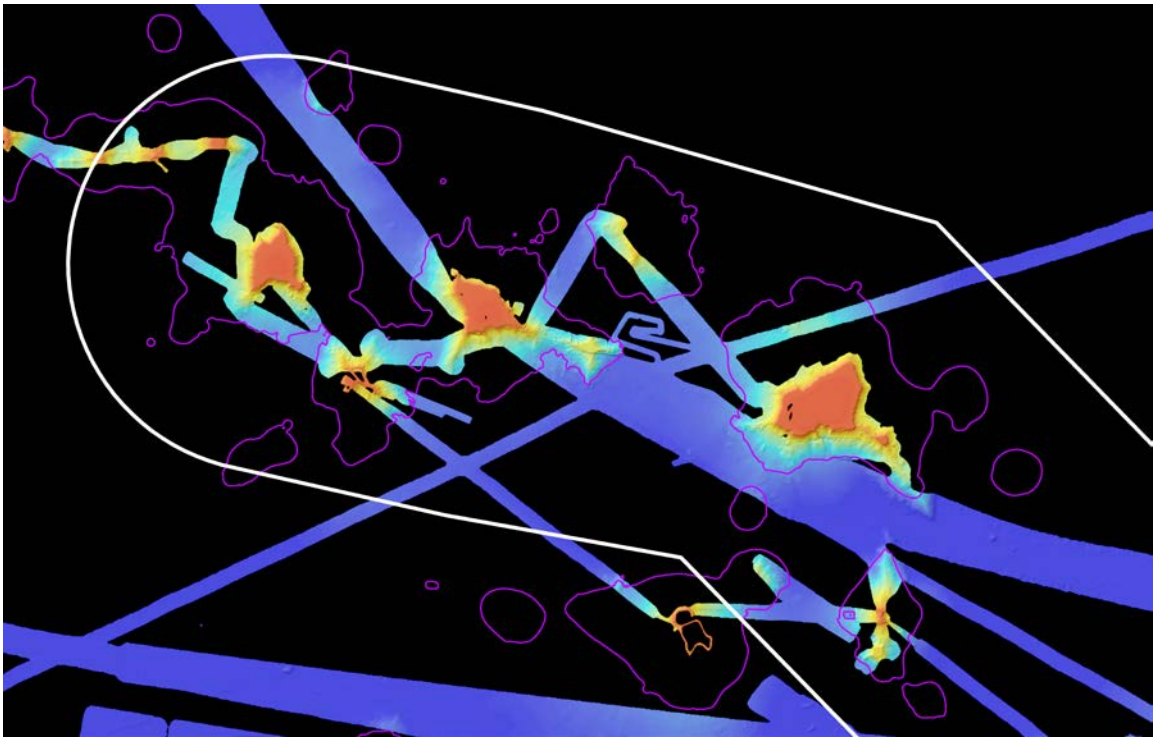
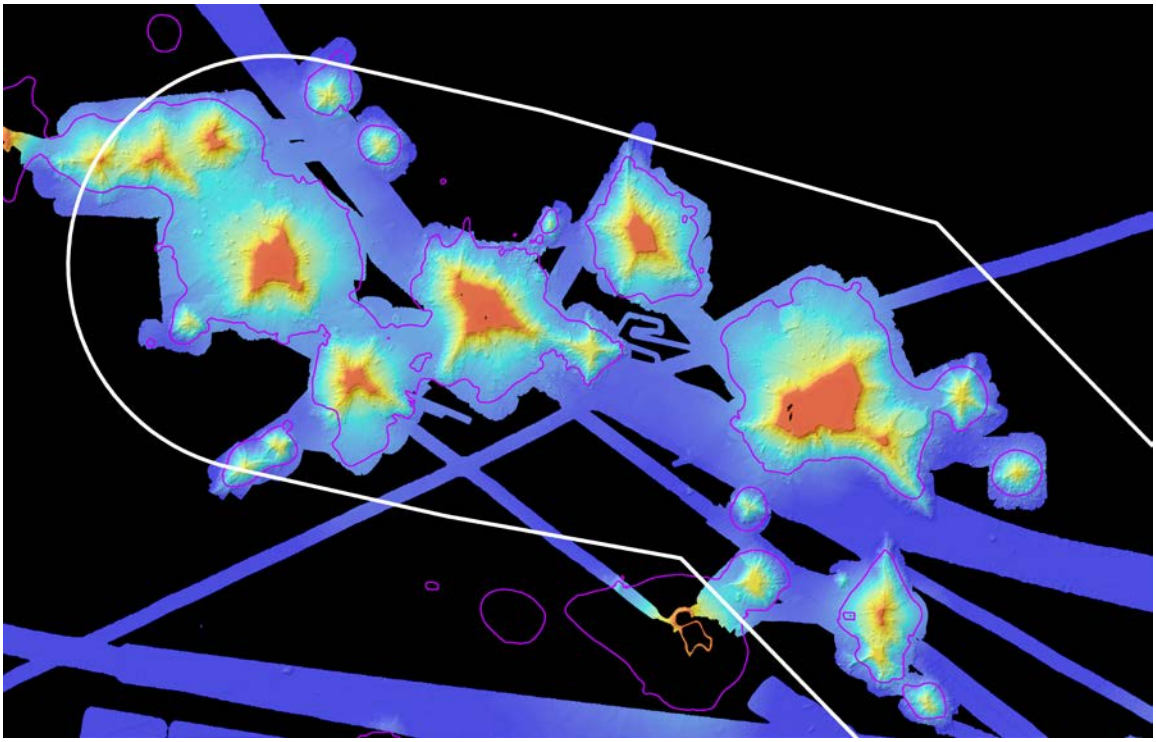


Figure 1: Google Earth image of the Falkor ship track (yellow line) during cruise FK140307. The white line shows the boundary of the Papahanaumokuakea Marine National Monument in the Northwestern Hawaiian Islands. Red dots are the CTD station locations and green dots are the XBT station locations. The ship departed from, and arrived back into the port of Honolulu shown near the right edge of the image.



a)



b)

Figure 2: a) Image of the existing "good to high quality" multibeam bathymetry coverage prior to the cruise in the northern section of the monument located within UTM zone 1. These data were collected primarily by NOAA CRED and the University of Hawaii. The white line is the monument boundary and the purple lines are the 4,000 m contours created from SMRT30 satellite altimeter data. b) Image of the multibeam bathymetry coverage after the cruise. FK140307 added approximately 61,000 km^2 to the multibeam coverage in this region of the Pacific.

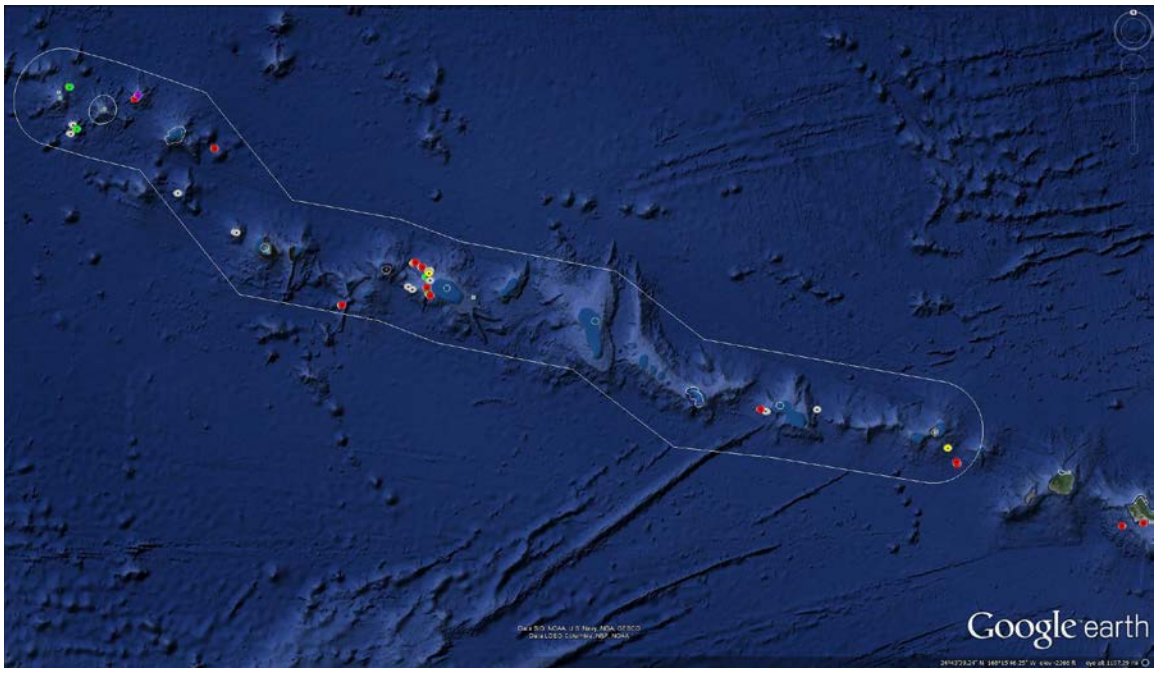


Figure 3: Google Earth image of the marine mammal observations made during cruise FK140307. The white line shows the boundary of the Papahanaumokuakea Marine National Monument in the Northwestern Hawaiian Islands. Different colored dots represent different types of mammals (red: sperm and humpback whales, yellow: pilot whales, green: dolphins, purple: monk seals, and gray: unidentified cetaceans).

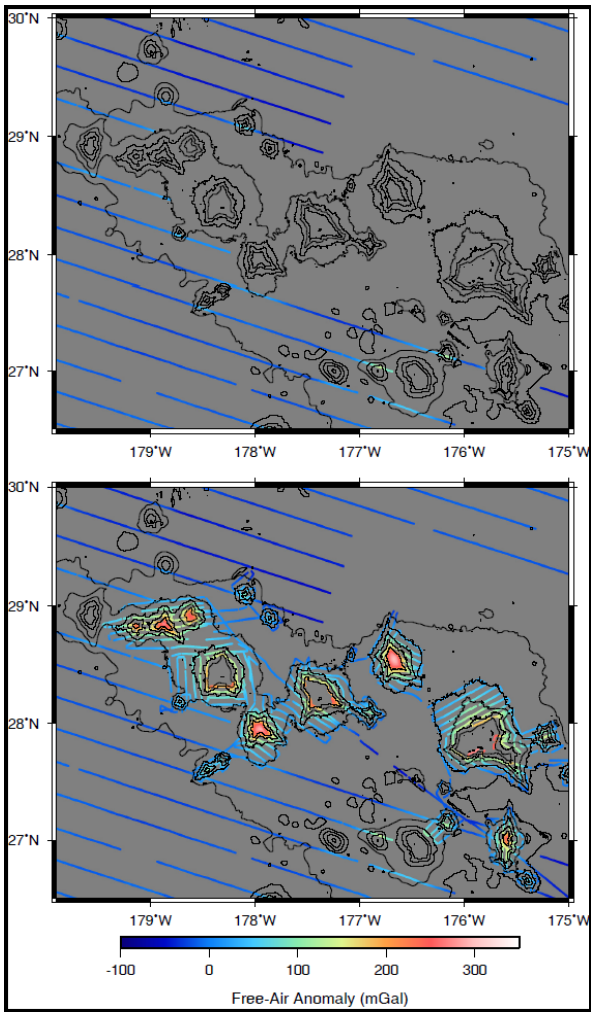


Figure 4: Free-air Anomaly maps of the survey region (UTM Zone1) before (top) and after (bottom). Data reduction is as described in the Gravity section of the report. Contours are 1000m intervals and were generated from a synthesis of SRTM30_PLUS satellite altimetry and multibeam data from the Falkor. This figure was produced using computer program: Generic Mapping Tools v 4.5.12.

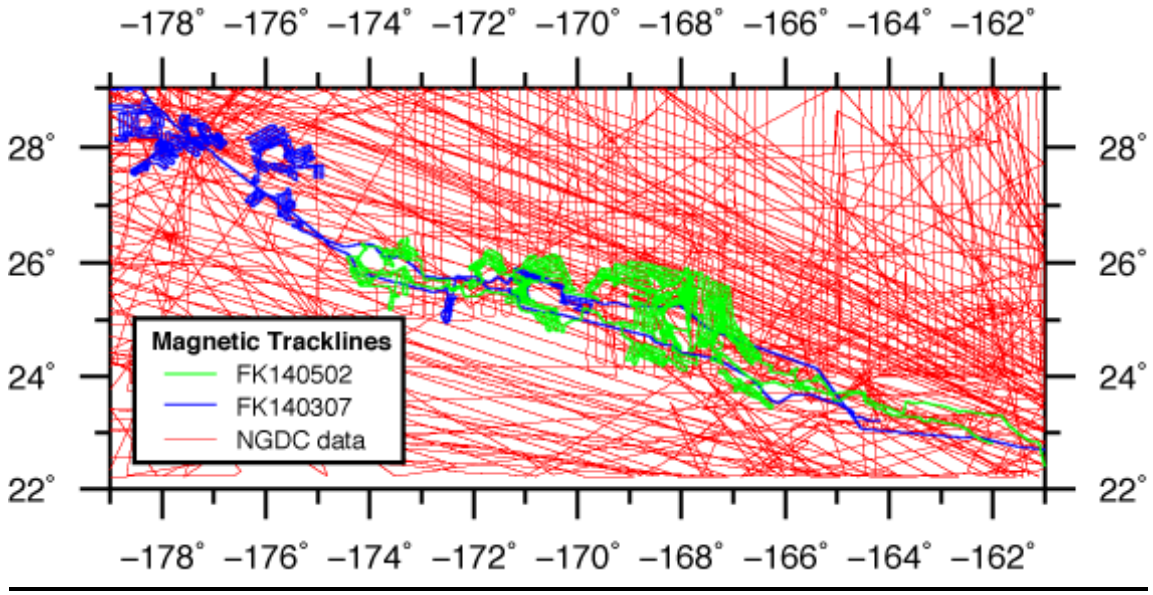


Figure 5: Ship tracks showing the extent of the magnetometer data collected during this cruise (FK140307 in blue) and for the following cruise (FK140502, green). Tracks showing data collected on previous cruises are shown in red.

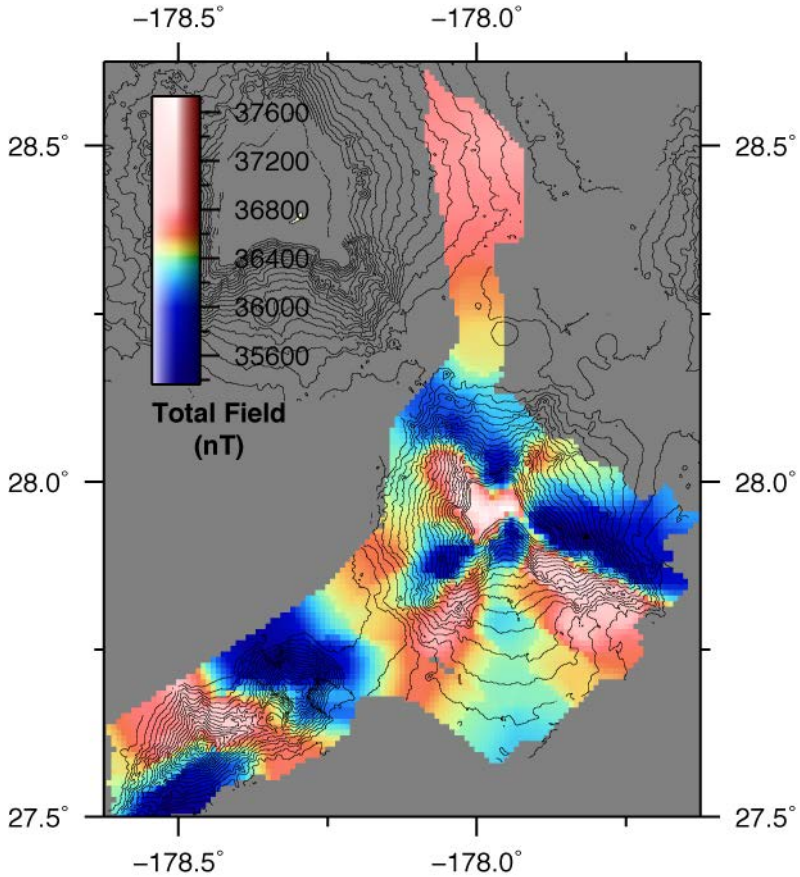


Figure 6: Example of the total field magnetometer data obtained during the cruise. The main feature in the center of the image is Nero Seamount, located just southeast of Kure Atoll.

FK140502 Report

1. Ship Name: R/V Falkor

2. Cruise Dates: 02/05/2014 to 06/06/2014

3. Cruise Number: FK140502

4. Ports-of-Call: Honolulu, Honolulu

5. Participating Organizations: University of Hawaii's (UH) Hawaii Undersea Research Laboratory, UH Department of Geology and Geophysics, UH Hawaii Mapping Research Group, NOAA Office of National Marine Sanctuaries (ONMS) and the Papahanaumokuakea Marine National Monument (PMNM), NOAA Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division (CRED), NOAA National Observer Program (NOP), Woods Hole Oceanographic Institute (WHOI), the National Science Foundation (NSF), and the University of Sydney School of Geosciences, the University of British Columbia (UBC).

6. Geographic Areas: All project operations took place in the Papahanaumokuakea Marine National Monument in the Northwestern Hawaiian Islands. The primary areas of operation within the monument were seamounts and banks located in UTM Zone 2. Additional secondary areas of operation included the St Rogatien Banks and French Frigate Shoals located in UTM Zone 3.

7. Names and addresses of the on board Chief Scientist and Co-chief Scientist:

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8. Cruise Objectives

This was the second of two cruises under the project titled "Volcanic platforms, ancient reefs, ridges, and seamounts: mapping the Papahānaumokuākea Marine National Monument". The six objectives listed in the report for the first cruise (FK140307) are the same for this cruise and are provided below.

Objective 1: Map seamounts and rift zone ridges located in the northern half of the monument. This survey focuses on Mn-crust habitats and the discovery of new high density coral and sponge beds that are associated with seamount and ridge topography.

Objective 2: Map drowned reef terraces on Gardner Pinnacles that reach depths of at least 2,000 m. The focus will be to complete mapping that has already been started, thereby improving our understanding of the geologic history of this important volcano.

Objective 3: Map the 50-150 m depth range around Laysan Island, Gardner Pinnacles, Pioneer Bank and if time permits, Raita Bank. The focus will be on the monument's important mesophotic zone habitats however drowned reefs are also found in this depth range. This objective will therefore be synergistic with objective 2.

Objective 4: Complete mapping of the ridge southeast of French Frigate Shoals.

Objective 5: Acquire gravity and magnetics data for the purpose of identifying the precise origin and locations of the volcanoes under the various banks and seamounts in UTM Zones 1 and 2 of the monument.

Objective 6: Document encounters with cetaceans and monk seals inside the monument for the purpose of improving our understanding of the effects of multibeam sonar on marine mammals.

9. Cruise Summary (A)

As mentioned in the report for the first cruise of this project (FK140307), this second cruise was not part of the original proposal but rather the result of an award of 36 additional ship days. It was set up as the final component of a graduate level Spring semester course for the University of Hawaii (UH) Geology and Geophysics Department (i.e, G&G 614 Field Study), with 7 of the 11 science team members being students. The gravimeter and magnetometer used for the first cruise were again used on this cruise to acquire gravity and magnetics data as a fifth objective. Also, similar to the first cruise, a trained marine mammal observer was part of the science team to oversee activities related to objective 6.

Multibeam Surveys

Similar to the first cruise, this second cruise was one of the more successful multibeam mapping efforts the chief scientist had ever been on. No days were lost to mechanical problems, instrument problems, or weather and the acquired data are of very high quality.

Mapping was conducted 24 hrs a day during all 36 days of this cruise, with the exception of the periods between Honolulu and the monument boundary on May 2 and June 6, when the systems were purposely turned off. Within the monument, 66,000 km^2 of seafloor were mapped, 5,000 km^2 more than the first cruise, which is attributed to our obtaining a permit to use XBTs in the monument to obtain sound velocity profiles (Figs. 1 and 2). XBTs can be deployed while the ship is actively mapping whereas CTDs require the ship to stop mapping for 60-90 min each day.

Unlike the distinct seamounts found in UTM zone 1 during the first cruise, the volcanic platforms in UTM zones 2 and 3 were much larger and conjoined down to a depth of 4,000 m. The smallest isolated structure seen in this area was the Pioneer-Lisianski platform, which was still a sizeable feature. More data from other ships existed for this area before this cruise, however, the seamounts and banks were much larger than in UTM zone 1 and therefore it was not possible to map their entire extents between 50-4000 m. Instead we focused on mapping within the optimal depth range for the Falkor EM302 multibeam system, which was generally between 1,000 to 4,000 m. While the shallower bank and seamount tops remain to be mapped, this cruise still made a significant contribution to the overall goal of mapping all significant features in the monument.

Of particular interest was Gardner Pinnacles, where the ship spent close to 2 weeks of time. Most of this gigantic volcano, possibly the largest on earth, has now been mapped, revealing a curious secondary cone, landslides, and large numbers of drowned reef terraces, the most prominent of which shows an unusually high and dramatic upturned edge. Furthermore, off its northern side spanning the monument boundary is an unusual field of small to medium sized structures that are either volcanic or have resulted from a major landslide event.

While seamounts were the highlight features of the first cruise, landslides and rift zone ridges were the highlight features of this cruise. Significant landslides clearly occurred off Maro reef as well as other banks in this area. Much to our surprise, a large landslide appeared to have taken place on eastern side of the rift zone ridge extending south from Pioneer bank. This is the only example we are aware of, of a landslide taking off a significant portion of a ridge, resulting in a razor sharp summit edge that extends for miles. This summit has been confirmed as one of the most amazing deep sea coral habitats found so far in the monument. Without the additional mapping from this cruise, the mechanism by which this summit was created would have remained hidden.

The entire extent of the rift zone ridge extending north from St Rogatien bank was another major feature mapped during this cruise. Unlike Pioneer ridge, this ridge is completely intact and is the largest such ridge in the monument. Multiple layers of drowned reef terraces can clearly be seen on its flat summit, which has not been investigated by either ROV or submersible to date.

Finally, some of the cruise time was dedicated to completing the coverage along the south side of the French Frigate Shoals ridge (see objective 4 above) and attempting to map selected mesophotic reef locations on Gardner, Pioneer, Raita, and Laysan Banks

(see objective 3 above). The most dramatic mesophotic reef structures were found on the southern tip of Raita and the southwestern side of Gardner Pinnacles, both at a depth between 40-60 m. However, we admittedly did not spend a significant amount of time on this objective because of the narrow swath widths mapping in these depths and the slow speed the ship had to be operated at for safety reasons.

Cetacean Observations

A total of 34 encounters with marine mammals occurred and were documented on this cruise. The locations of the encounters are shown in Figure 3. The species included sperm whales, killer whales, pilot whales, minkie whales, and dolphins. The species seen during several encounters could not be identified due to distance and brevity of the encounter. Similar to the first cruise, we were surprised by the relatively low number of encounters with humpback whales in the monument. As with the first cruise, we did encounter sperm whales off the west side of Maro reef, indicating that this area may be of potential interest to cetacean researchers. In all cases, the trained observer did not see any obvious negative reaction by any species that came within the multibeam sonar ensonification volumes. All of the behaviors such as "spy hopping" were typical of those seen by the trained observer on other boats and ships not engaged in mapping activities.

10. Cruise Summary (B)

Gravity Surveys (prepared by Jonathan Tree)

The Bell BGM-3 marine gravimeter outputs hourly logs and one daily log of gravity data that can be used for processing and data analysis (data files with suffix of *.GEF and *.RGS respectively). Daily processing was completed after the GMT day was finished and one full day of data along our track was available. Traditional gravity data processing was completed by filtering the gravity data string using filter tools from Linux and Generic Mapping Tools Version 4.5.12. The data reduction steps taken include resampling on 15 second increments, applying a spatial and vector correction to account for our location on the Earth and our velocity in a given heading (termed the Eötvös correction), and lastly the removal of the Earth's gravitational field by the IGRF 1984 approximation for gravity. Qualitative observation of this data was conducted using MATLAB and quality individual "lines" were extracted from the continuous dataset of the day's duration. The quality of the line was defined as containing no anomalous data spikes that correlate with sharp turns of the ship or other unknown data interference. The product of this reduction is called the Free-air Anomaly and is plotted in the supplementary Figure 4 and 5. This is the baseline product that will be analyzed further and submitted to the NGDC for archiving once full analysis has been completed. This future work will focus on geophysical questions such as:

1. By locating extraordinarily dense subsurface structures relict from volcanic magma chambers, how many individual volcanoes were formed in this region of the Hawaiian Chain?
2. How much of the volcanic materials were extrusive (i.e., lava flows on the surface) vs intrusive (i.e., magma filled chambers, dikes, and sills)?

3. How strong is the lithosphere that holds up these volcanoes? Does this strength change when a larger or smaller volcanic load is emplaced atop of it? Does it vary with the size/volume of the seamount?
4. This area seems to be the onset of major volcanic production by the Hawaiian hotspot, which of these seamounts are the first that are constructed of multiple volcanoes making one edifice?

Data that was collected in this region contributes greatly to the existing geophysical data of this region, making these data invaluable to the marine geophysical community. Although there are sporadic areas which have been surveyed prior to our expedition, the density and coverage of data over seamount flanks and other areas of interest was lacking. The addition of these data will yield valuable insight in to one of the most interesting sections along the Northwest Hawaiian Ridge.

The Bell BGM-3 is a power and motion sensitive instrument, and consequently, any disruption to these elements will yield "non-valid data". Providentially, only minor amount of data were lost due to these conditions and does not significantly inhibit our dataset. Unlike the first leg (FK140307), rough seas and CTD stations were not problematic in stabilization problems with the gravimeter. This time however, planned/unplanned power outages resulted in the gravimeter's power source interruption and reliance on its external battery source. These power disruptions did not last long enough to harm any components of the device itself, but data was lost during these instances.

Magnetics Surveys (Prepared by Brian Shiro)

The Geometrics G-882 marine magnetometer collected 28,611,216 measurements of the total magnetic field throughout the FK140502 cruise between 3 May 2014 at 10:04 GMT and 5 June 2014 at 21:05 GMT. The instrument was towed 169 meters behind the *Falkor's* aft deck A-frame at an average depth of 8.6 meters below sea level depending on the ship's speed. Raw data was collected at 0.1 second intervals and stored redundantly via both the SCS and Hypack systems. Science watchstanders monitored the magnetometer's data stream in the Science Control Room and logged its activity every hour for the duration of the cruise. The marine technicians and scientists temporarily retrieved and then redeployed the instrument whenever the ship dropped its speed below 5 knots or executed unusual maneuvers. These intervals introduced short data gaps of less than two hours duration during the following periods: 5/4, 5/28, 5/29, 6/2, and 6/3.

Since the magnetometer data did not include geographic position, it was necessary merge the 10 Hz magnetometer data with the ship's 1 Hz navigation data by decimating them to a common time sampling using a one-second median filter. The gridded total field data shown in Figures 6 and 7 illustrates how the FK140502 cruise improved magnetic data coverage compared with pre-existing data from other sources. Going forward, we will further reduce the data by subtracting the International Geomagnetic Reference Field (IGRF), applying the Reduction to Pole (RTP) correction, and performing a crossover analysis. This will draw out small-scale magnetic variations that can provide relative age

constraints on features identified in the sonar and gravity data. Thus, the magnetic information could prove to be an age discriminator to distinguish Hawaiian age from Cretaceous age seamounts within the Papahānaumokuākea Marine National Monument.

11. Summary of Measurements and Samples Taken

NO	UNITS	DESCRIPTION
65,908	Square Kilometers	EM 302 Multibeam bathymetry data with a depth range of 28-5,188 m
65,908	Square Kilometers	EM 302 Multibeam backscatter data with a depth range of 28-5,188 m
6,300	Square Kilometers	EM 710 Multibeam bathymetry data with a depth range of 28-2,034 m
6,300	Square Kilometers	EM 710 Multibeam backscatter data 28-2,034 m
15,254	Kilometers	Gravity data with continuous data feed along ship track
15,254	Kilometers	Magnetometer data with continuous data feed along ship track
2	Stations	CTD Casts providing depth, salinity, temperature, and sound velocity to a maximum depth of 1000 m
35	Stations	XBT Casts providing depth, temperature, salinity, and oxygen to a maximum depth of 1,000 m
34	Observations	Data records of encounters with cetaceans that include location, date, time, species, and behavior

12. Moorings, Bottom-Mounted Gear and Drifting Systems
No

13. Equipment Used

The following types of equipment were used during this cruise.

a) *Falkor*'s Kongsberg EM 302 multibeam sonar

This instrument is owned and operated by SOI and is permanently mounted on the *R/V Falkor*. A link to a downloadable document providing complete specifications is provided on the following Kongsberg website:
http://www.km.kongsberg.com/ks/web/nokbg0397.nsf/AllWeb/A915A71E90B6CFAEC12571B1003FE84D/$file/306106_em_302_product_specification.pdf

b) *Falkor*'s Kongsberg EM 710 multibeam sonar
This instrument is owned and operated by SOI and is permanently mounted on the *R/V Falkor*. A link to a downloadable document providing complete specifications is provided on the following Kongsberg website:
http://www.tdi-bi.com/vessels/em710_.pdf

c) *Falkor*'s CTD
This instrument is owned and operated by SOI and was used to acquire sound velocity profiles for the multibeam sonar systems. A description is provided on the SOI website:
http://www.schmidtocean.org/story/show/47

d) *Falkor*'s Deep Blue Expendable Bathythermographs (XBTs)
These instruments provide a cheap time efficient means of acquiring sound velocity profiles for the multibeam sonar systems. A link to a downloadable document providing a description of the Deep Blue XBT used is provided below:
http://www.sippican.com/stuff/contentmgr/files/0dad831400ede7b5f71cf7885fdeb110/sheet/xbtxsv.pdf

e) Bell Aerospace BGM-3 marine gravimeter
The BGM-3 Gravimeter is a geophysical device that measures accurately and precisely the acceleration of gravity due to the Earth's gravity field. This device was rented from Woods Hole Oceanographic Institute's 'WHOI' organization: the Multidisciplinary Instrumentation in Support of Oceanography 'MISO' and is part of their Potential Fields Pool Equipment 'PFPE' that was installed by WHOI engineers on March 5-6, 2014. The device was located in the dry lab, slightly above water level and slightly portside of the ship's centerline. The gravimeter was land tied prior to departure on March 6th, 2014. Data from the BGM-3 was continuously logged along the ship track and was paired with the *R/V Falkor*'s navigation data from the *Falkor*. Output measurements of observed gravity were expressed in units of mGal.

f) Geometrics G-882 marine magnetometer
A Geometrics G-882 marine magnetometer was provided by the University of Hawaii. The device works by detecting variations in the resonance of a self-oscillating split-beam cesium vapor. It has an accuracy of <3 nT over an operating range of 20,000 nT to 100,000 nT. The G-882 was attached to a multiconductor tow cable that was paid out to a maximum of 169 meters from the stern of the ship using an electrical winch on the *Falkor's* aft deck and supported by the ship's A-frame. The offset between the A-frame and the ship's GPS antenna is 22 meters, giving a total offset of 191 meters between magnetometer and the ship's logged geographic coordinates. The raw data was digitized

by the Geometrics DC/Data junction box in the *Falkor's* dry lab and then logged via an automatic rsync process to the ship's SCS system on channel COM28. Falkor marine technicians also chose to log the data the independently via the ship's Hypack system. Data was logged continuously at 10 samples per second (10 Hz) and included a timestamp, gamma value in nT, Larmor frequency level, and scaled instrument depth.

14. Station Plots

Two Google Earth images were emailed to "cruise.report@schmidtocean.org" showing a) the ship track and positions of CTD (red) and XBT (green) casts, and b) locations of all cetacean observations made on this cruise.

15. Other

a) Seven graduate students were among the participants on this cruise, four from the University of Hawaii's Department of Geology and Geophysics, two from the University of Sydney's School of Geosciences, Geocoastal Research, and 1 from the University of British Columbia. All seven gained considerable experience in carrying out projects at sea on large oceanographic vessels and were required to learn the basic functions of Hypack 2013 for survey line planning and magnetometer data acquisition, Seafloor Imaging Systems (SIS) for multibeam data visualization and acquisition, Saber and Caris for multibeam data editing and processing, SVP editor and Turo XBT for XBT data acquisition and processing, and Fledermaus for multibeam bathymetry and backscatter data visualization and display.

b) A post-cruise data management meeting was held on June 27 to create the plan for distributing the data collected on both this cruise and the first cruise for this project (FK140307). The meeting was attended by participants from UH (HURL, G&G, and HMRG) and NOAA CRED, with SOI's Allison Miller listening in via Skype. Following the creation of a metadata file by the PI, the plan includes the submission of raw and edited data files to the NOAA National Geophysical Data Center (NGDC) by the end of July, 2014. Processed bathymetry and backscatter data in the form of GRDs, ASC, and image files will be posted on the Hawaii Undersea Research Laboratory's (HURL) website. Other websites including PMNM, NOAA CRED, and SOEST will also either be a source for the data or will provide a link to the data on the HURL website. CTD and XBT data will be provided to Pat Caldwell of NOAA's National Oceanographic Data Center (NODC). Cetacean observation data and the GIS project created from the data will be provided to NOAA Pacific Islands Regional Office (PIRO) that is responsible for protected resources and Endangered Species Act (ESA) section 7 consultations.

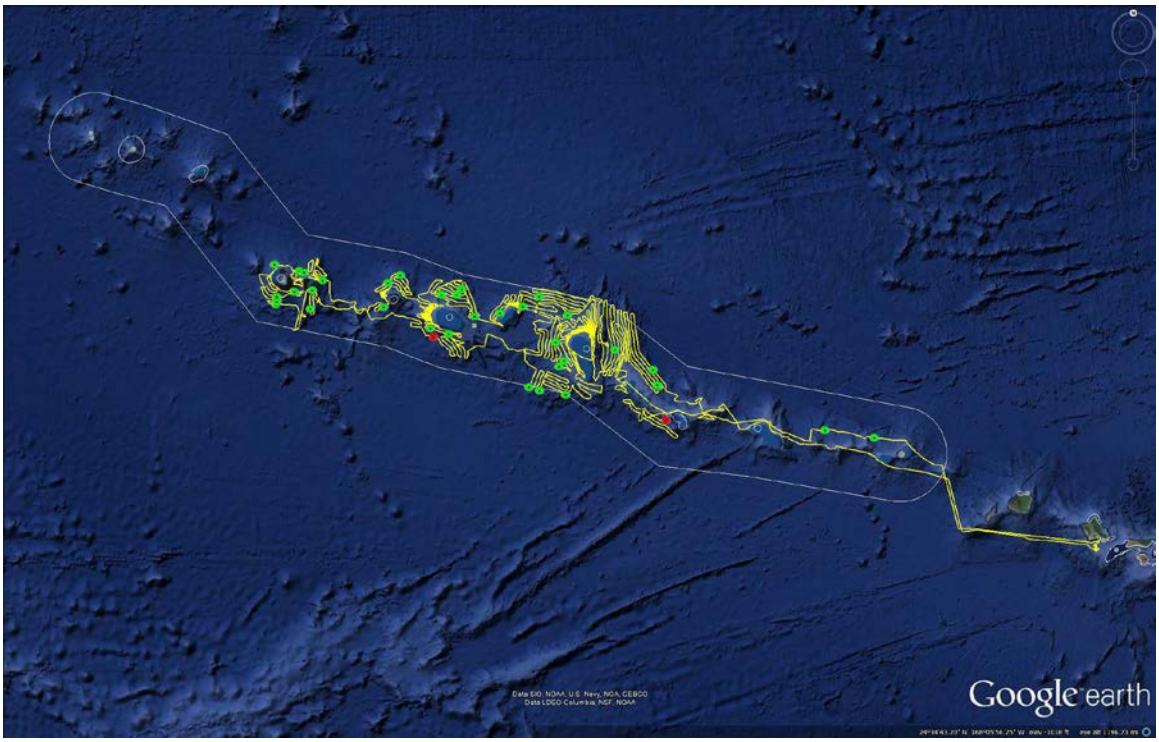
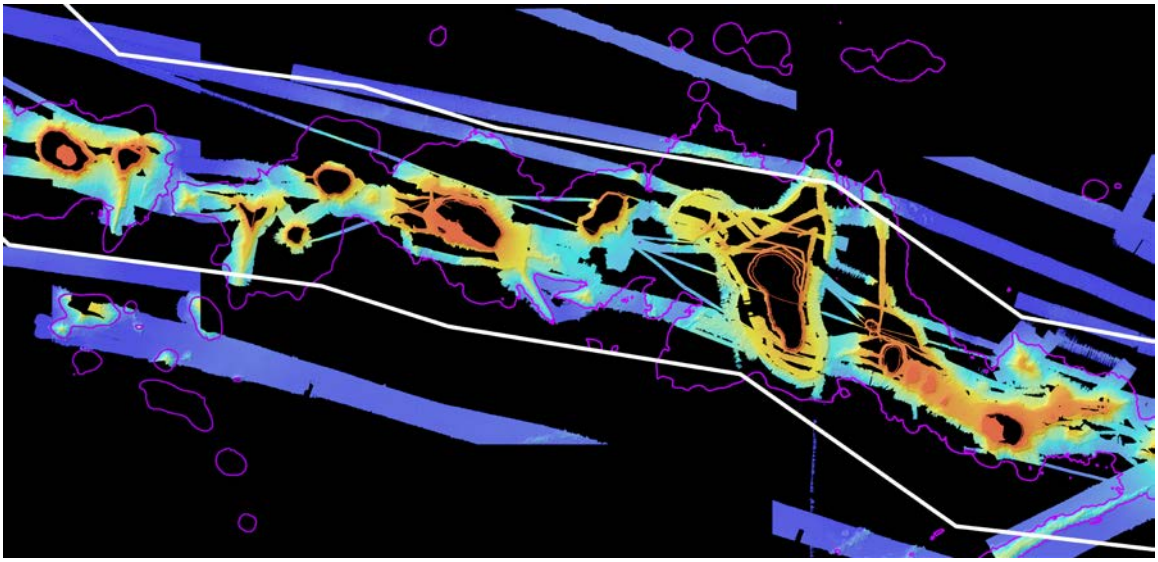
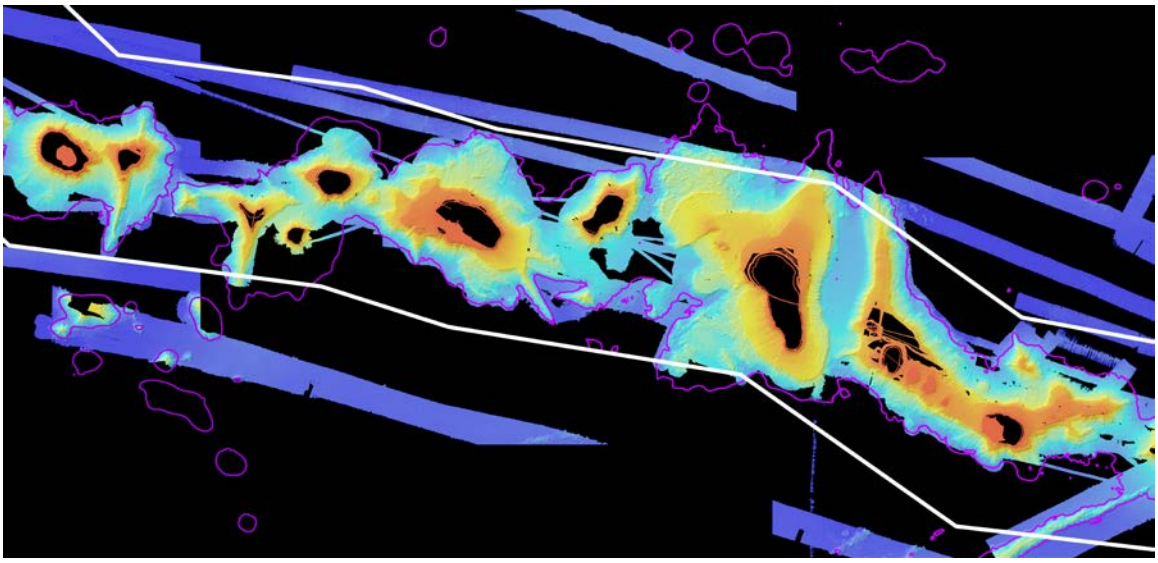


Figure 1: Google Earth image of the Falkor ship track (yellow line) during cruise FK140502. The white line shows the boundary of the Papahanaumokuakea Marine National Monument in the Northwestern Hawaiian Islands. Red dots are the CTD station locations and green dots are the XBT station locations. The ship departed from, and arrived back into the port of Honolulu shown near the right edge of the image.



a)



b)

Figure 2: a) Image of the existing "good to high quality" multibeam bathymetry coverage prior to the cruise in the middle section of the monument located within UTM zone 2 and the western part of UTM zone 3. These data were collected primarily by NOAA CRED and the University of Hawaii. The white line is the monument boundary and the purple lines are the 4,000 m contours created from SMRT30 satellite altimeter data. b) Image of the multibeam bathymetry coverage after the cruise. FK140502 added approximately 66,000 km^2 to the multibeam coverage in this region of the Pacific.

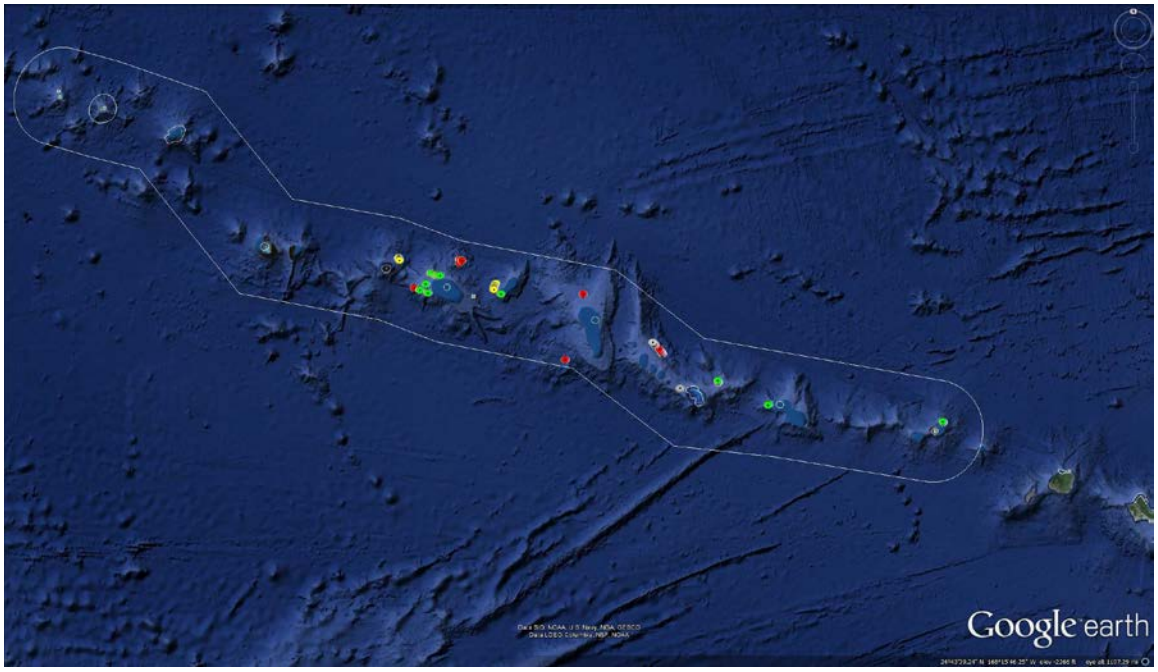


Figure 3: Google Earth image of the marine mammal observations made during cruise FK140502. The white line shows the boundary of the Papahanaumokuakea Marine

National Monument in the Northwestern Hawaiian Islands. Different colored dots represent different types of mammals (red: sperm and killer whales, yellow: pilot and minkie whales, green: dolphins, and gray: unidentified cetaceans).

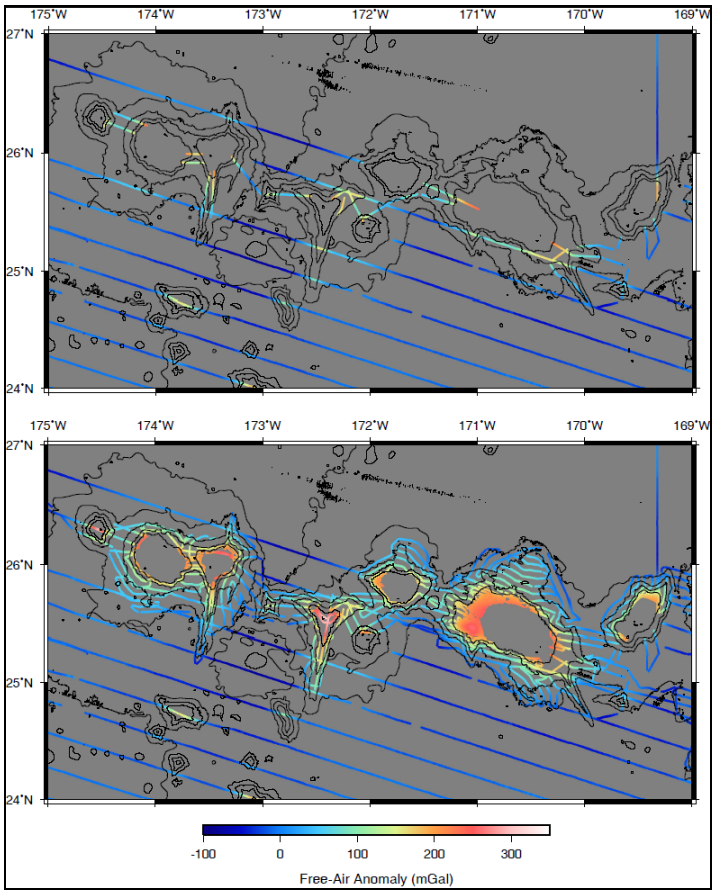


Figure 4: Free-air Anomaly maps of the survey region (~UTM Zone 2) before (top) and after (bottom). Data reduction is as described in the Gravity section of the report. Contours are 1000m intervals and were generated from a synthesis of SRTM30_PLUS satellite altimetry and multibeam data from the Falkor. This figure was produced using computer program: Generic Mapping Tools v 4.5.12.

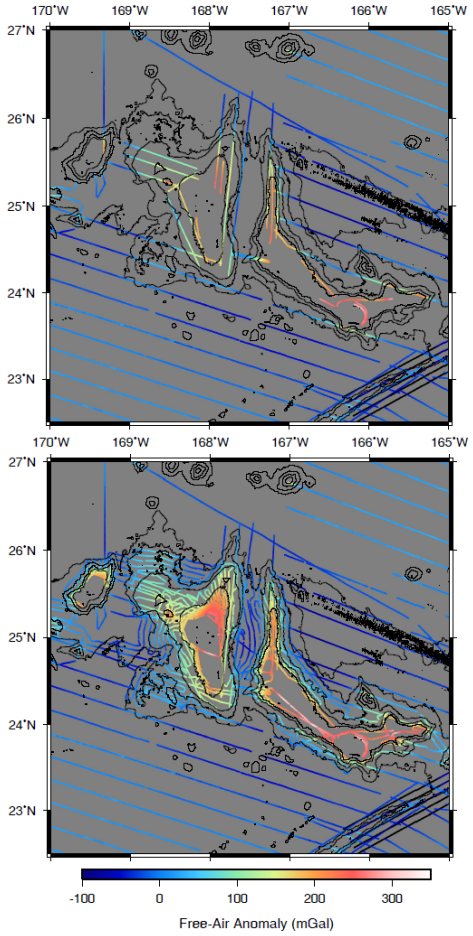


Figure 5: Free-air Anomaly maps of the survey region (~UTM Zone 3) before (top) and after (bottom). Data reduction is as described in the Gravity section of the report. Contours are 1000m intervals and were generated from a synthesis of SRTM30_PLUS satellite altimetry and multibeam data from the Falkor. This figure was produced using computer program: Generic Mapping Tools v 4.5.12.

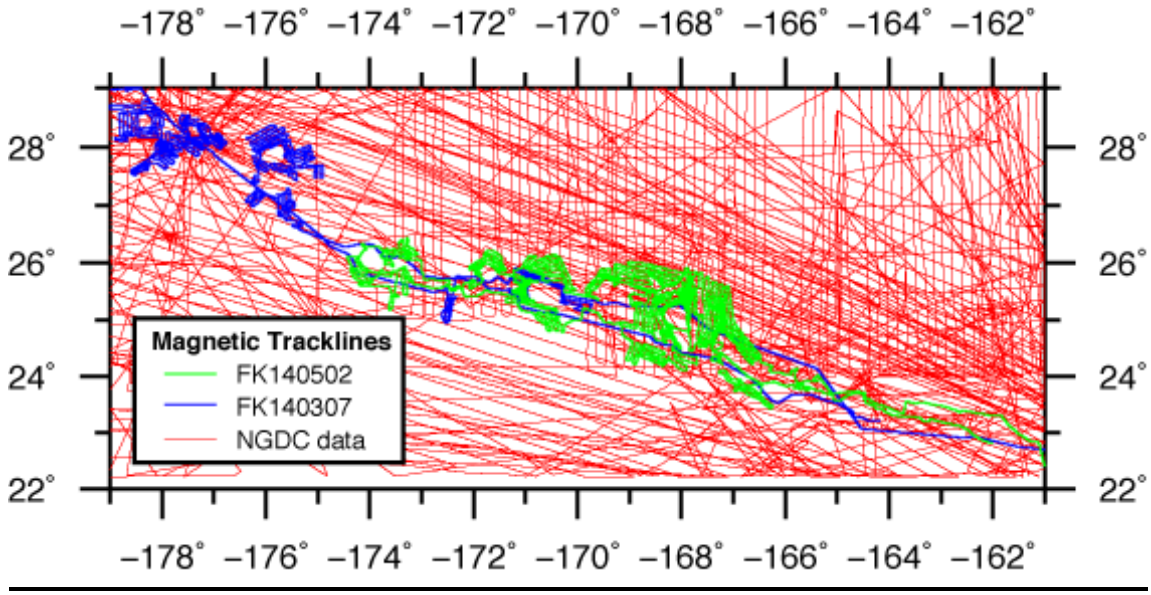


Figure 6: Ship tracks showing the extent of the magnetometer data collected during this cruise (FK140502 in green) and for the previous cruise (FK140307, blue). Tracks showing data collected on other ships during previous cruises are shown in red.

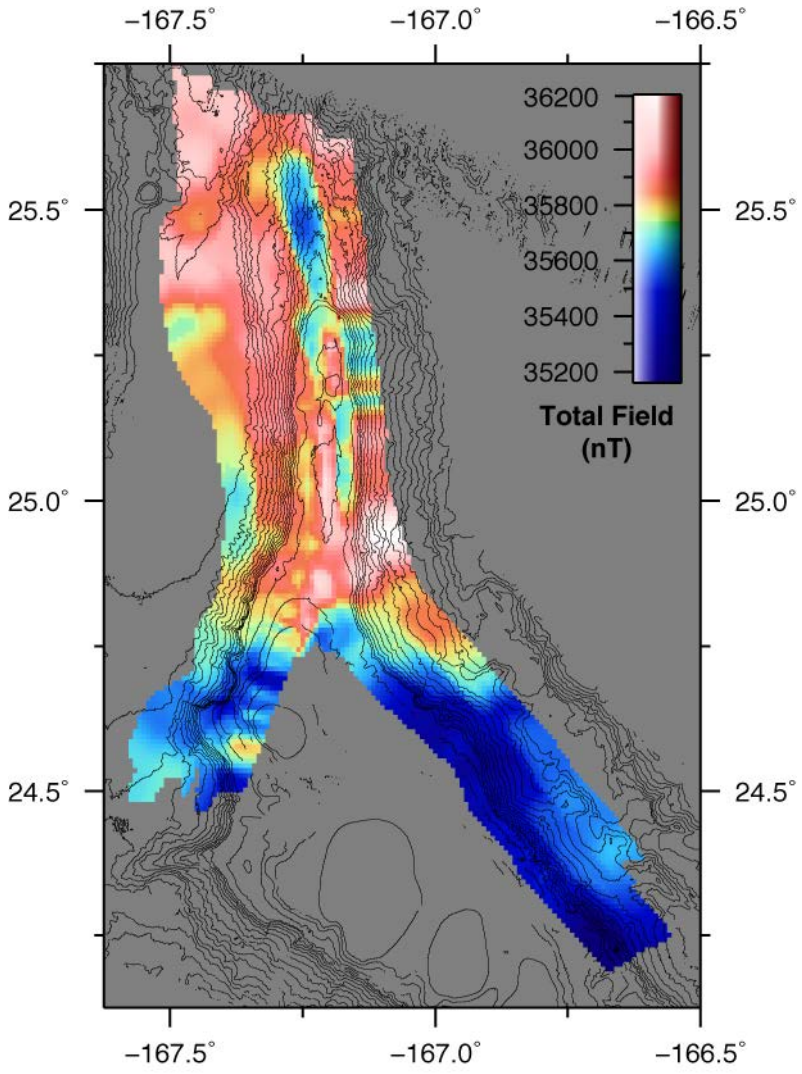


Figure 7: Example of the total field magnetometer data obtained during the cruise. This location is the large rift zone extending north from St Rogatien banks.